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The study of Forbush decrease event and geomagnetic disturbances during the solar magnetic polarity reversal

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Abstract Transient decrease in cosmic ray intensity followed by a slow recovery typically lasting for several days, is identified as Forbush decrease event. One such a large Forbush decrease event has been observed from April 8-20, 1990, which occurs during the period of solar magnetic polarity reversal in solar cycle 22 The onset of Forbush decrease took place on April 8-9, 1990 and attained its maxim on 9th April, 1990 After that the long recovery phase started which continued up to 20th April, 1990. It is noteworthy that the three successive events of sudden storm commencements (SSC's) occurred on 9, 12 and 17th April 1990, which cover total time span of Forbush decrease events Further, a sudden decrease in Dst values in similar pattern of cosmic ray decrease, indicates a significant relation in depression in cosmic rays and Dst values The geomagnetic index A_p has also been observed to increase abruptly on April 9, 1990 An attempt has been made to explain the cosmic ray decrease alongwith the interplanetary/geomagnetic disturbances that occurred during which there was a solar magnetic polarity reversal

Keywords Forbush decrease, geomagnetic disturbances

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Forbush decrease (Fd) are transient decreases of cosmic ray intensity followed by a slow recovery typically lasting for several days. Since the discovery of such decrease in cosmic ray intensity by Forbush in 1938, investigators have been searching for the cause of these decreases in the fields and flows emitted from the Sun [1–4]. In 1975 Barouch and Burlaga [5] have reported that the high magnetic field regions (blobs) in the interplanetary space are associated with Forbush decrease. Further, this have been demonstrated that these cosmic ray decreases are not related to the turbulence or random motions in the field, while only the regions of high field strength in interplanetary space are found responsible for causing Forbush decreases. These regions consist of interplanetary magnetic loops (or blobs)/ clouds of ordered field topology, ejected from active solar regions, interplanetary shocks having comparatively ordered field structure, the turbulent fields in the environment of shocks, corotating high speed streams or simply tangential discontinuities [1,6]. Various mechanism for the Forbush decreases have been proposed by the scientists. They identify the decrease as the reflection at the front of the blast wave [7] the deflection of particles by extended structures of ordered field configurations [6], gradient B drift in the environment of shocks of rather ordered structures [5,8] and the scattering of particles in the turbulent field region between the shock front and magnetic clouds [9,10] In this manuscript, we have studied the Forbush decrease event of April 8-20, 1990 to the variation of interplanetary plasma parameters The various investigators of Fds established that these decreases are produced by perturbation in the interplanetary condition and that these perturbations originate from shock waves, coronal mass ejections, solar flares, high velocity solar wind streams [11–14]. Recently, Ifedili [15] has pointed out the heliospheric propagation of galactic cosmic rays is independent of the polarity of heliospheric magnetic field This paper investigates the cosmic ray decrease and interplanetary disturbances that occurred during the period 8–20 April, 1990; a period during which there was a solar magnetic polarity reversal.

The Fd event is identified from the hourly plots of cosmic ray intensity compiled and published by Nagoya University, Japan. The cosmic ray intensity daily values are obtained from Oulu, Finland [long. 65.1 N, 25.5 E, altitude 15 m, 9-NM-64] super neutron monitor. Interplanetary magnetic field (IMF) components along with solar wind plasma data at 1 AU obtained from the Interplanetary Monitoring Platform

(IMP-8) satellite provided by National Space Science Data Centre, has been used in the present study to investigate the large Forbush decrease event on 8th April 1990 in relation to geomagnetic activity. Introduced in 1964, the ring-current index Dst measures primarily the ring-current magnetic field while A_E defined in 1966 by Davis and Sugiura measures variations in the auroral electrojets [16]. Using these indices, one can investigate the low latitude as well as high latitude effects Daily values of geomagnetic Dst and A_E index are used to derive the possible relationship of cosmic rays with geomagnetic activity.

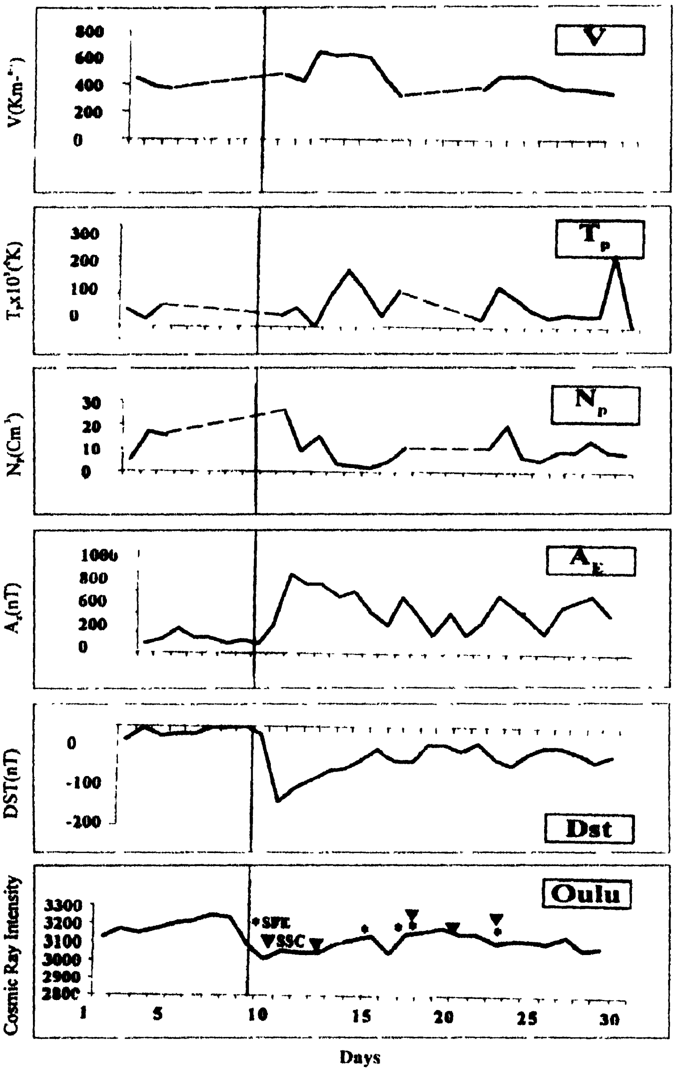

Figure 1. Cosmic rays (Oulu neutron monitor), geomagnetic Dst and A_E index alongwith solar wind parameters *i e* proton density Np, proton temperature Tp and velocity V are plotted for the month of April 1990 on day to day basis. (Dashed lines...... show the data gap)

As in the case of Forbush decreases, the characteristic time is of the order of days [5], we have used the pressure-corrected daily mean values of cosmic ray intensity from April 1-30, 1990 as recorded by Oulu neutron monitor. Results are shown in Figure 1 for the month of April, 1990 on day to day basis, lower panel of figure depicts the cosmic ray intensity variation while the second and third panel show the geomagnetic index A_E and Dst respectively. Rest upper panels display the daily values of interplanetary parameters such as solar wind plasma density Np, temperature Tp and wind velocity V respectively. Figure 2 depicts interplanetary

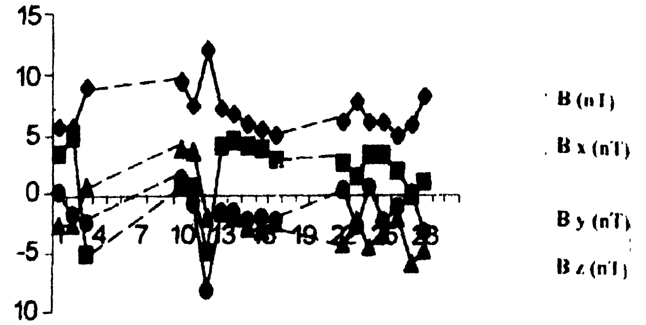

Figure 2. Interplanetary magnetic field B and its components Bx, By and Bz are plotted for the month of April 1990 on day to day basis (Dashed lines .. . show the data gap).

magnetic field B and its components represented by Bx, By and Bz. Transient decrease is detected during 8-20 April 1990. After acquiring the maximum amplitude of decrease, the recovery takes place in couple of days. The maximum amplitude of Fd is ~ 6.5% for Oulu station. We have observed one sudden storm commencement and a large solar flare on 8th April, 1990 which are marked in Figure 1 The above solar flare is linked with NOAA active region 6007 (N 24 E 20). The sudden storm commencement (SSC) which occurred at 8 hr. UT on 9th April, 1990 marked the arrival of interplanetary shock wave at the Earth. The shock arrival time coincided with the sudden increase in IMF intensity and the solar wind plasma speed. The observation of enhanced level in IMF and plasma speed during the Forbush decrease are consistent with the model of Parker [7]. Occurrence of SSC event is also noticed during the time of minimum decrease in cosmic ray intensity. Other events of solar flares and SSCs are observed during the recovery period of Forbush decrease which may lead to further cosmic ray depressions approaching by the end of April 1990. It is around the onset of Forbush decrease, the IMF intensity and solar wind plasma density are enhanced. The daily values of interplanetary magnetic field B and its components (Bx, By, Bz) are available only around the onset time of Fd. In this event, B is high and Bx (the radial component) is very small Another two components By (west ward) and Bz (south ward) are found higher than Bx, Bz is further enhanced with occurrence of SSC; such enhancements in B, By, Bz components indicate large depressions in the interplanetary region in which cosmic rays are supposed to be in diffusion-convection state or in a trapped state. The observations presented in this paper, are consistent with the hypothesis that Forbush decreases are effectively produced by an enhanced high intensity large-scale interplanetry magnetic field [5]. We note that the recovery starts immediately after the decrease (~ 18 hours) and is completed within 7 days after the minimum of cosmic ray decrease. Another cosmic ray decrease is observed for 24 hours on April 17, 1990 after having a solar flare event on the preceding day; the intensity started its recovery taking ~ 16 hours. This is followed by two more solar flare events and one sudden commencement of storm.

Remarkable fluctuations are seen in geomagnetic Dst and A_E indices, these two show distinctly different variation during the period of Forbush decreases. The value of Dst index shows significant transient decrease in similar pattern as that of Forbush decrease. The geomagnetic disturbances index Dst recorded at low latitudes, which comes from the west-ward flowing zonal current system called the ring current, and another geomagnetic index A_E which represents the geomagnetic field fluctuations in mid-latitudes, it is assumed that the massive compression of the magnetosphere and anormous intensification of the large scale magnetospheric current system reflected in Dst and A_E lead to a significant geomagnetic effect on cosmic ray measurement near the Earth.

The storm commenced on April 9 and occurrence of the flare on 8th April, which was largest flare with importance 2 N, an intense geomagnetic storm of magnitude 278 nT took place on April 10, causing a drastic change in Dst index. Such type of solar and geomagnetic/interplanetary changes may be the cause behind the large Forbush decrease of April 1990

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